Life Support & Habitability and
Planetary Protection Workshop

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Advanced Extravehicular Activity
Breakout Group Summary

AEVA Breakout Group - Participants

Joe Kosmo/NASA-JSC, Lead
Carl Walz/NASA-HQ's
Sharon Cobb/NASA-HQ's
Dr. Anthony Hanford/Jacobs ESCG
Dr. Dean Eppler/SAIC
Alan Perka/NASA-JSC

<u>External Contributors</u>:
Dr. Steve Hoffman/SAIC
Amy Ross/NASA-JSC
Ed Hodgson/Hamilton Sundstrand Corp.
Dave Grazoisi/ILC Dover
Jack Bassick/David Clark Co.

Planetary Protection Advanced EVA – Specific Breakout Group Tasks

Breakout Group charged with following tasks:

- Identify potential contaminants and pathways for AEVA systems with respect to **forward** and **backward contamination**
- Identify **plausible mitigation alternatives and obstacles** for pertinent missions
- Identify **topics that require further research and technology development** and **discuss development strategies with uncertain PP requirements**
- Identify **PP requirements that impose the greatest mission/development costs**
- Identify **PP requirements/topics that require further definition**
- **Overall Recommendations**

Purposes of Planetary Protection & Implications

Forward Contamination

Assumption: - Missions carrying humans to Mars will contaminate the planet

- **Protect mission science objectives :**
  - Unambiguous detection of past and present life
    - Implies avoiding biological and chemical contamination at science sites until science objectives achieved
      - » Need knowledge of transport and persistence of EVA released contaminants in planetary environment
      - » Evaluate representative EVA target measurements and sensitivity
    - Enable controlled experiments on transport / propagation / persistence of exobiology
  - Undisturbed study of surface geology / mineralogy in natural Mars atmosphere
    - Likely oxygen, and water vapor issues – potential alteration of samples
  - Uncontaminated samples for science in habitat and on return
- **Protect Mars life if found :**
  - For study
  - For survival

Potential Planetary Forward Contamination Pathways & Characteristics

- **Vehicle Landing Phase:** (S71-38189)
  - Exhaust plume products and ejecta material
    - Chemical contamination; Spores / viruses/ etc. on vehicle exterior surfaces
      - earth atmosphere exposure before & during launch is virtually guaranteed
    - Disturbance of surface region for x-radius distance
- **Habitat Deployment Phase:**
  - Off-loading or Transport from Lander (if not integral to Lander)
    - Autonomous/Robotic Mode:
      - Surface disturbance for x-radius
      - Vent & Material Composition products from robotic assisted operations
    - EVA-Assisted Mode:
      - Surface disturbance for x-radius
      - Vent & Material Composition products from human assisted operations
        - » CO_2, water vapor, trace contaminants due to suit/PLSS/airlock operations and leakage
- **Normal EVA Surface Operations Phase:**
  - Routine daily/weekly activities
    - Airlock operations
      - Vent gases, water vapor, trace contaminants, particulates, organisms in atmosphere
    - Transport to EVA worksites (2003e57386 & 2004-00408)
      - Surface disturbance for x-radius by rovers (both un-pressurized & pressurized vehicle systems)
      - Vent & Material Composition products
    - EVA surface traverses (2004e43512 & 2003e57466)
      - Surface disturbance for x-radius
      - Vent & Material Composition products
      - Suit surface, tool, & equipment contaminants from human contact in don / doff / servicing / maintenance
        - skin oils & acids, hair, dander, microbial...
  - Geologic/Astro-biological sample collection activities (surface & sub-surface ops)
    - All of the above concerns associated with human-assisted operations (2004e39632 & 2004e43534)
- **ISRU Operations Phase:** (2004e43567)
  - All of the above concerns; perhaps magnified based on the extent of operations.
  - Venting / waste streams from ISRU operations – and contamination of those streams from equipment contact, human contact with ISRU systems, exchange with or back flow from habitat fluids.

Representative EVA-Associated Planetary Surface Forward Contamination

- **Airlock Operations:**
  - Based on ISS configuration (2-crewmember size)
    - Depress to 3.0 psia (20.7 kPa) and vent residual gas to space - (vent amt. ~ 2.0 lbs of gas per depress cycle)
    - Due to high power requirements & pump efficiency; planetary surface airlocks would operate similarly
  - Based on a "Minimum Volume" airlock (2-crewmember size)
    - Assuming volume is = 2X suited crewmember volume
    - Gas loss would be ~1/2 of the ISS case or 0.97 lbs. per depress operation
    - Minimum volume airlock will aggravate human contact contamination issues for don/doff and servicing operations unless a "Suit-port like" interface to the habitat is adopted.

- **Space Suit Operations:**
  - Total suit assembly leakage allocation based on representative Class I flight Shuttle EMU (each suit)

	Ground-Level	In-Space Level
• Arms (each)	31.5 sccm/air	9.0 sccm/O2
• Lower torso	24.5 sccm/air	7.0 sccm/O2
• Gloves (each)	10.5 sccm/air	3.0 sccm/O2
• Upper torso	21.0 sccm/air	6.0 sccm/O2
• Helmet	7.0 sccm/air	2.0 sccm/O2
• TOTAL LEAKAGE	136.5 sccm/air	39.0 sccm/O2

  - Additional leakage constituents from portable life support system (PLSS)
    - Vent system loop (connector fittings)
    - Oxygen supply source (gaseous or cryogenic)
    - Heat removal system (sublimator/water boiler; ~1 lb/hr.)
    - Potential venting during assisted operations, emergency operations, EVA recharge or equipment change-out activities

- **Additional Potential Contamination Constituents:**
  - Trace chemical contaminants associated with suit leakage ; Lubricants associated with surface support vehicles and suit bearings
  - Suit surface contaminants from habitat and human contact
  - Elastomeric/fabric materials from surface support vehicles and outer materials of space suit
    - Mechanical abrasion
    - Off-gassing of volatiles

Representative Space Suit System
Potential Leakage Path Areas

- Based on a modular constructed suit assembly for logistics interchangeability and commonality of components (represented by planetary prototype NASA-JSC MK III advanced technology suit) :
  - Identified approx. 50 separate potential leakage path areas represented by static seals, dynamic seals, and connector hardware pass-thru locations.
  - The potential suit leakage path areas include:
    - 30 individual modular element static seal interfaces
    - 15 individual bearing system dynamic seals
    - Rear-entry hatch closure seal area
    - 4 cryo-backpack connector hardware pass-thru locations
  - Does not take into consideration all individual gas bladder pattern heat sealed or adhesively bonded seams or natural permeation characteristics of the bladder material based on wear and abrasion
  - Given the above information, the robustness of the MK III suit is representative of the fact that after > 950 hrs. of pressurized use over the past 17 years, total leakage rates are on the order of 1,500 – 2000 sccm/min. after normal 40-hr. maintenance periods
    - This equates to current Class III Shuttle EMU suit leakage rates experienced during Neutral Buoyancy Laboratory (NBL) operations

Trace Contaminants Produced By Humans

(from Shuttle EMU Design & Performance Requirements Specification-SVHS 7800)

Compound	Maximum Allowable Concentration PPM	Biological gm/human-day
Ammonia	25	0.25
Methane	1000	0.047
Acetaldehyde	10	0.000083
Acetone	100	0.00013
Ethyl Alcohol	17	0.004
Methyl Alcohol	13	0.0014
n-Butyl Alcohol	3	0.0013
Methyl Mercaptan	0.1	0.00083
Hydrogen Sulfide	1	0.000075

- The above values represent trace contaminant human products that would be components of all space suit leakage and vent gases from airlocks/habitats.
- Various toxicological trace contaminant products and Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants (SMAC's) developed by the National Research Council Committee on Toxicology can be found on web-site:
  - http://www1.jsc.nasa.gov/toxicology/SMACbooks.htm

Trace Contamination Limitations

(from JSC 20584; Spacecraft Maximum Allowable Concentrations for Airborne Contaminants)

- The **MAC** (Maximum Allowable Concentration) of Total Organics Exclusive of Fluorocarbons is 100 ppm Pentane Equivalents.

A. Families of Compounds	Mole. Wt.	Units	MAC
1.Alcohols (as Methanol)	32	mg/m3	10
2.Aldehydes (as Acrolein)	56	mg/m3	0.1
3.Aromatic Hydrocarbons (as Benzene)	78	mg/m3	3.0
4.Esters (as Methyl Butyrate)	102	mg/m3	30
5.Ethers (as Furan)	68	mg/m3	0.11
6.Halocarbons			
a. Chlorocarbons (as Chloroacetone)	93	mg/m3	0.5
b. Chlorofluorocarbons (as Chlorofluoromethane)	68	mg/m3	24
c. Fluorocarbons (as Trifluoromethane)	70	mg/m3	12
7.Hydrocarbons (as N-Pentane)	72	mg/m3	3.0
8.Inorganic Acids (as Hydrogen Fluoride)	20	mg/m3	0.08
9.Ketones (as Diisobutyl Ketone)	142	mg/m3	29
10.Mercaptans (as Methyl Mercaptan)	48	mg/m3	0.2
11.Oxides of Nitrogen (as Nitrogen Dioxide)	46	mg/m3	0.9
12.Organic Acids (as Acetic Acid)	60	mg/m3	5
13.Organic Nitrogens (as Monomethyl Hydrazine)	46	mg/m3	0.03
14.Organic Sulfides (as Diethyl Sulfide)	90	mg/m3	0.37

Continuation of Trace Contaminant Limitations

B. Specific Compounds

	B. Specific Compounds	Mole. Wt.	Units	MAC
1.	Ammonia	17	mg/m3	17
2.	Hydrogen Cyanide	27	mg/m3	1.0
3.	Methane	16	mg/m3	3800

The MAC values represent the maximum total for a family of compounds and are based on the most toxic member of the family, except in the case of hydrocarbons (N-Pentane chosen for convenience of instrumentation calibration). Total is defined as the summation of compounds in a family. If measurements are made which will identify a specific compound, then a MAC value will be determined for the "known" compound. The "known" compound's measured concentration is subtracted from the family's "unknown" constituents which is then compared to the family MAC value. Until all members of the family are identified, the MAC value for the family of compounds will remain unaltered. See JSC 20584, Spacecraft Maximum Allowable Concentrations for Airborne Contaminants, for original specification source.

C. Gas Sampling

A gas sample shall be taken of the gas in the canister. The gas shall reside in the test item for 10± 1 minutes and then be drawn into an evacuated cylinder. Contaminants from the canister shall not exceed the following requirements:

Name	Max. Allowed
Trichloroethylene	0.1 ppm
Chloroform	0.1 ppm
Methyl Chloroform	0.1 ppm
Vinylidine Chloride	0.1 ppm
1.1.2.2 Tetrachloroethane	0.1 ppm
Alcohol, Isopropyl	5.0 ppm
Toluene	3.0 ppm
Freon TF	5.0 ppm

Purposes of Planetary Protection & Implications

Back Contamination

Assumption : - Humans will be exposed to Mars surface materials

- Maintain livable / healthy environment in Mars surface habitat:
  - Avoid airlock contamination or isolate airlock
    - Separate "dust lock" or "suit port"
  - Avoid crew contamination & assure decontamination in suit don / doff ops.
  - Decontaminate sample containers, tools, instruments, before & during transfer into habitat
  - Contaminant control & removal capabilities in habitat
- Avoid risks to earth:
  - Decontamination capability for crew & all returning items
  - Sample isolation capabilities through life of mission
  - Sample / measure / observe test systems in ALS or others in habitat?
  - Implications of crew as test population – is long stay and early assured exposure desirable / essential? – How long & how much is enough?
    - Quarantine issues

Potential Planetary Backward Contamination Pathways & Characteristics

- **Normal EVA Surface Operations Phase:**
  - Routine daily/weekly activities:
    - Airlock operations
      - Transport of dust & regolith materials from surface into airlock and subsequent habitat living areas
      - Crew contamination during don – inhalation / ingestion during EVA – inseparable transfer into habitat & to earth
    - Return from remote EVA worksites & surface traverses
      - Potential transport of "non-documented/classified " surface materials back into airlock/habitat living areas
  - Geologic/Astro-biological sample collection activities (surface & sub-surface ops)
    - Handling of samples (in-situ) or in habitat laboratory for analysis
  - Transfer of EVA prep / servicing / maintenance items into habitat
    - Surface contaminants trapped and captured in suit fabric folds & cavities, seal regions, porous materials, between layers, etc.
      - Limitations of practicable cleaning processes prior to airlock entry / in airlock
  - ISRU Operations Phase:
    - All of the above concerns; perhaps magnified based on the extent of operations

Planetary Protection
Plausible Mitigation Alternatives and Obstacles

- Regarding Human-EVA Supported Surface Activities:
  - Minimize surface contact area of initial human-EVA supported activities:
    - Use robotic precursors (tele-operated or autonomous mode) to scout & survey intended EVA worksite locations and potential science way-point stations prior to human intervention
      - Obstacle – may be the cost & time overhead associated with robotic vehicle operation; also, limitations associated with robotic vehicles as such (lack of real-time decision making, intuition and judgment)
  - Identify "safe" and "no-go" zones adjacent to and within x-radius distance of lander/habitat location for method of control for human-EVA supported traffic
      - Obstacle – may not be able to totally exclude "chance encounter" with "oasis-of-life"; potentially restrictive for critical surface operations (location of ISRU plant or power-plant distribution elements)
  - Reduce or eliminate EVA-system element contamination sources
    - Vent gases, leakages, trace chemical contaminants, material abrasion, etc.
      - Obstacle – not totally practical; through normal use and wear conditions over time, all potential contamination sources will increase and accumulate. Also a real restriction on life support technology choices.
  - Screen, identify and catalog all earth-based "signature" materials associated with EVA-system elements in order to recognize against potential "alien" life-bearing materials:
    - Develop "Contamination Materials Reference Guideline"
      - Obstacle – time and cost maybe excessively prohibitive; also, may not fully capture all associated materials and constituents
  - To potentially mitigate "backward" PP contamination, quarantine, isolate or discard all EVA surface-exposed hardware items (other than scientific samples) at habitat base-site as a "non-return" to Earth policy:
    - Provide "peel-off layer" over portions of suit to remove/discard prior to airlock entry
    - "Decontaminate" or stow (i.e., dust ante-room area) EVA hardware items prior to airlock entry
      - Obstacle – need to assess logistics and costs associated with "throw-away" versus "re-use" philosophy.
        - » Limited effectiveness given transfer of contaminants to crew and habitat

PP EVA System Topics Requiring Further Research & Technology Development

- Improved space suit design features consistent with PP needs, especially for the demands of human activities on the Martian surface located away from pressurized habitats and rovers: (from ICES Tech. Paper No.2003-01-2523; "Planetary Protection Issues in the Human Exploration of Mars"
  - Define specific surface task activities that would require the implementation of appropriate PP measures
  - Potential modification or redesign of suit/PLSS venting systems applicable to Mars surface situations

- Describe and define the potential physical (chemical or biological) impacts that the identified suit/PLSS vent/leakage constituents would have in regard towards PP "forward" contamination concerns:
  - Determination of levels of control that are possible or needed for EVA systems; suits, PLSS, airlocks, rovers
  - Develop baseline information on release/escape of microbes from suits and airlocks and development of detection and monitoring sensors and procedures
  - Determine what effect would the natural Martian environment (UV, radiation, thermal, pressure) have towards <u>"natural mitigation"</u> of potential Earth-based contaminants (?)

PP Requirements Imposing Greatest EVA Mission/Development Costs

- Definition of "Design-To" requirements is critical to understanding costs:
  - We have a pretty good idea of what we vent, and how much...what we don't know is what is acceptable and what isn't...
- The definition of "PP" needs in relation to how it impacts EVA mission & system element development costs should be considered and interpreted as follows:
  - Since EVA operations will have the most direct (wide spread) physical interaction with the Martian surface on a daily/weekly routine basis, "PP" needs should be considered in the following terms to mitigate hardware & operations costs:

<u>"Plausible Protection" Criteria</u>

1. Identify, quantify and catalog all potential EVA system contamination sources
2. Implement reasonable preventative measures (by combination of design and procedures) to reduce contamination sources that would be technically feasible and non-cost prohibitive
3. Screen and manage the contamination stream
4. Eliminate any unknown constituents –

   Given the intimate human interactions with suit systems including internal atmosphere composition, complexity and variability of the source, this may not be totally practical at a level that will protect science objectives. – It is not an unreasonable hypothesis that dominant contaminants in an earth life signature may also be top priority signatures in a search for Mars life.

Overall EVA Systems PP Recommendations

- Define specific surface task activities that would require the implementation of appropriate PP measures
  - Need specific input to define tasks and requirements vs. PP measures
- Describe and define the potential physical (chemical or biological) impacts that the identified suit/PLSS vent/leakage constituents would have in regard towards PP "forward" contamination concerns
  - Conduct human suited subject chamber tests to determine actual products vented during suit operations
- Determine what levels of PP "backward" contamination control are possible or needed for EVA systems; suits, PLSS, airlocks, rovers
  - Develop appropriate operational protocol to minimize transfer of contamination products into the habitat
  - Consider the requirements associated with periodic inspection and maintenance, in order to maximize the time between inspection and minimize crew exposure to Martian materials
- Determine what effect would the natural Martian environment (UV, radiation, thermal, pressure) have towards "natural mitigation" of potential Earth-based contaminants (?)
  - Information on release/escape of microbes from suits and airlocks and development of detection and monitoring sensors and procedures
  - Develop tests based on human subject tests described above